IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent application of	:	
Leslie Michael LEA et al.	:	Group Art Unit 1763
Serial No. 10/043,265	:	Examiner Alejandro Mulero, Luz
Filed January 14, 2002	:	
PLASMA PROCESSING APPARATUS	:	

DECLARATION of DR. LESLIE LEA
UNDER 37 C.F.R. ¶1.132

Commissioner for Patents
Customer Service Window, Mail Stop RCE
Randolph Building
401 Dulany Street
Alexandria VA 22314

Sir:

In connection with the above-identified application, I hereby declare as follows:

1. I am presently the Deputy Chief Executive Officer and Chief Technical Officer at Surface Technologies Systems Plc, the assignee of record of the above-identified application.

2. I hold Doctorate and Masters degrees in the Science and Applications of Electric Plasmas from Oxford University, with a first degree in Physics (1st class honors) from Southampton University. After graduating, I worked as a Post Doctoral Research Assistant at Oxford University, working closely with the Culham Laboratory of the United Kingdom Atomic Energy Authority (UKAEA). After two years I joined the UKAEA, (later AEA Technology), at the Culham Laboratory, as a Research and Development Scientist gaining ten years

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experience in scientific project management, the design of plasma and ion beam systems, and management of the construction and testing of these systems. Applications on which I have worked include heating and diagnostics for plasmas in nuclear fusion experiments, commercial plasma processing systems, and plasmas related to defense purposes. I have significant experience in designing and constructing plasma diagnostics, and in constructing computer models of plasma systems. I am a Member of the UK Institute of Physics, and have served on one of its Committees.

3.   I have reviewed the U.S.P.T.O. Examiner's comments contained in the Office action dated January 11, 2005. As best understood, the Examiner appears to take the position that the attenuation of ions occurs in each of U.S. patent no. 4,990,229 (Campbell et al.), European publication no. EP 0676793 (Maeda et al.), and U.S. patent no. 4,810,935 (Boswell) inherently. However, as explained below, the opposite effect occurs in the systems of these references.

4.   Each of Campbell et al, Maeda et al. and Boswell describe helicon type plasma sources that use a specific geometry of antenna to launch a helicon (whistler) wave into a region where the magnetic field is of a defined strength, so that efficient energy transfer occurs between the wave and the electrons of the plasma formed in that region. The overall effect is to increase the efficiency of energy transfer from the RF power supply to the plasma, forming a much denser plasma (higher ion and electron numbers) than would be found in a standard ICP system.

5.   The history and operating principles of helicon systems may be found for example in "Principles of Plasma Discharges and Materials Processing" M. A. Liebennan and Al. J. Lichtenberg, Wiley-Interscience Publication. Page 441 of this publication is attached. Helicons are propagating whistler wave modes in a finite

diameter, axially magnetized plasma column, i.e. it is a prerequisite of a helicon plasma source that there is an imposed axial magnetic field.

6. At FIGURE 13.19 of the attachment, it is clearly shown that the plasma (ion and electron) density increases with increasing imposed magnetic field strength for a fixed input RF power. Experimentally this is a discontinuous increase, but the overall result is diametrically opposite in effect from (a) that apparently attributed by Examiner to Campbell et al, Maeda et al. and Boswell, and (b) that described in the current application where an increase in the imposed magnetic field strength results in a reduction in the number of ions reaching the wafer.

7. One aim of the present invention is to reduce the number of ions that reach the wafer (to be processed) from a plasma source while allowing the majority of radicals (carrying no charge) from the plasma source to reach the wafer. The effect is to reduce the ratio of numbers of ions to radicals in the region of the wafer from that found in the plasma source.

8. The means for reducing the number of ions that reach the wafer may be an electromagnet operated from a DC power supply. The electrical current from the power supply may be set to give a chosen magnetic field strength and the level of this magnetic field strength determines the degree of reduction (attenuation) in the number of ions that reach the wafer compared to the number produced in the plasma source.

9. In embodiments of the present invention, reduction in the number of ions reaching the wafer occurs as the magnetic field strength is increased.

10. In the current application the plasma source is an inductively coupled plasma (ICP) system, in which RF power is coupled by an inductive (transformer action)

into the plasma and no separately imposed magnetic field is required for this system to operate.

11. I further declare that all statements made herein of my own knowledge are true, and that all statements or information are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Respectfully submitted,

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Dr. Leslie Lea

Date: 5 January 2006

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Attachment: Page 441 of "Principles of Plasma Discharges and Materials Processing" M. A. Lieberman and Al. J. Lichtenberg, Wiley-Interscience Publication.

becomes increasingly inefficient. A second transition is seen to $k_s \approx 3\pi/l_a \approx k_\perp$ with $n_0 \approx 2.7 \times 10^{11}$ cm^{-3}. Standing helicon wave effects may also play a role in this transition, as described in the next subsection. Figure 13.19 shows the roughly linear scaling of n_0 with B_0 predicted from (13.2.7) or (13.2.8), for a different source than that of Fig. 13.18. Again we see the density steps imposed by the antenna coupling condition. Depending on the specific experimental configuration, for example, the distance between the antenna and the outer surface of the source dielectric cylinder, the density steps are not always as evident as shown in these data. They may also be produced by large relaxation oscillations as the discharge "hunts" between helicon and inductive excitation modes. The antenna can also be designed to couple efficiently to a wide range of k_z's, reducing the importance of mode jumps in the density range of interest. Similar effects are seen for $m = 0$ mode helicons. This mode is excited by an antenna consisting of two circular coils of radius R, separated by a length l_a, carrying oppositely directed currents.

Helicon Mode Absorption

The helicon mode energy is believed to be transferred to the plasma electrons as the mode propagates along the column by collisional or collisionless (Landau) damping. The former mechanism transfers the energy to the thermal (bulk) electron population, while the latter mechanism can act to preferentially heat a nonthermal electron population to energies greatly exceeding the bulk electron temperature. There is considerable evidence that collisional absorption is too weak to account for energy deposition at low pressures (< 10 mTorr argon), although this mechanism may dominate at higher pressures. Landau damping is a process by which a wave transfers energy to electrons having velocities near the phase velocity $u_{ph} \approx \omega/k_z$ of the wave. (See, for example, Chen (1984) for an exposition of the phenomenon.) Chen (1991) has estimated the effective collision frequency ν_{LD} for Landau damping of the helicon
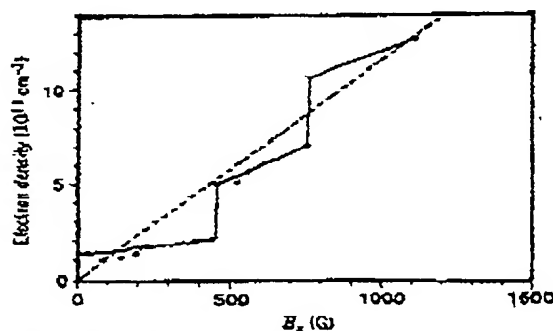

FIGURE 13.19. Measured density as a function of magnetic field at a fixed input power. The dashed line represents the resonance condition imposed by the antenna (Perry et al., 1991).